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**FILING DATE:** ***December 09, 2002***
**RELATED PCT APPLICATION NUMBER:** *PCT/US03/38746*

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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

**This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).**

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|---|---|

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☑ *Additional inventors are being named on the _______ separately numbered sheets attached hereto*

**TITLE OF THE INVENTION (500 characters max)**

Embedded Nanotube Array Sensor [ENTAS]

*Direct all correspondence to:* **CORRESPONDENCE ADDRESS**

☐ Customer Number ______ *Type Customer Number here* → *Place Customer Number Bar Code Label here*

*OR*

| | | | | | |
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**ENCLOSED APPLICATION PARTS *(check all that apply)***

☑ Specification *Number of Pages* 11
☐ Drawing(s) *Number of Sheets* ______
☐ Application Data Sheet. See 37 CFR 1.76
☐ CD(s), Number ______
☐ Other (specify) ______

**METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT**

☑ Applicant claims small entity status. See 37 CFR 1.27.
☑ A check or money order is enclosed to cover the filing fees
☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: ______
☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.
☑ No.
☐ Yes, the name of the U.S Government agency and the Government contract number are ______

*Respectfully submitted,*

SIGNATURE [signature]

Date 12/9/02

TYPED or PRINTED NAME Charles F. Rancourt

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Docket Number: RPI-776

## USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

# PROVISIONAL APPLICATION COVER SHEET
## Additional Page

PTO/SB/16 (02-01)
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| Docket Number | RPI-776 |
|---|---|

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Number ______ of ______

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# Embedded Nanotube Array Sensor [ENTAS]

Patent Application Number:

Publication date:

Inventor(s): Pulickel Ajayan (RPI), Seamus Curran (RPI), Emer Lahiff (TCD), Chang Y Ryu (RPI), Paul Stryjek (RPI)

Applicant(s): RPI

## Abstract

The present invention relates to nanosensors for detecting defect growth and structural change in aircraft and automotive components. These sensors provide continuous information on stress, strain, defects, thermal effects and cracking on critical aircraft structural components. This information is immediately analyzed by onboard data-basing providing aircraft structural analysis ensuring safety, decreasing aircraft maintenance lifecycle cost and increasing aircraft useful life.

**U.S. Patent Documents**

| | | | |
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| 5047719 | Sep., 1991 | Johnson et al. | 324/242. |
| 5485084 | Jan., 1996 | Duncan et al. | 324/242. |
| 5659248 | Aug., 1997 | Hedengren et al. | 324/232. |
| 5966011 | Oct., 1999 | Goldfine et al. | 324/243. |
| 6414483 | July.2, 2002 | Nath et al. | 324/232. |

## Claims

1. A composite wing and/or aircraft chassis to be made of a composite with an array of nanofibers providing:
    a) Aligned nanotubes or carbon fibers (now to be termed as 'nanosensors') embedded in an aircraft composite to act as the information gathering array
    b) A nanosensor contacted at either end to receive information on the changes in electronic currents and thermal conductivity
    c) The electronic current can be altered by bending, twisting and/or breaking the nanosensors embedded in the aircraft composite material
    d) Array of nanosensors designed to receive information relating to the performance of an aircrafts physical condition
    e) Detects cracking and growth of stress/strain components within the chassis
    f) Potential for using the nanosensor array as an antenna for transmit/receive capability
2. The information gathered within the aircraft chassis to be passed onto a data analysis computer where:
    a) The stress, strain, fracture content, breaking, cracking is calculated from the changes in the conductivity
    b) The thermal effects on the chassis is calculated
    c) The static build-up for different environments is calculated from changes in electrical conductivity near the surface
    d) The relevant information (structural changes that are a danger to the aircraft) to be transferred to the flight crew and/or maintenance crew.
3. The composite containing the nanosensors according to (1) to be made from predetermined selectively nanotube or carbon fiber growth
4. The nanosensors according to (1) and (2) to have diameters less than 1 μm and lengths greater than 1 μm
5. The array or nanosensors according to (1) to be dispersed according to structural needs within the composite
6. The nanosensors according to (1) to be contacted at their tips by electronic contacts (now referred to as 'nanocontacts')
7. The nanocontacts according to (6) can be diodes (Schottky or pn junctions) or metallic electrical contacts
8. The nanocontacts according to (6) can be organic (polymeric electronics), inorganic semiconductors or metallic contacts
9. The nanosensors according to (1) can act as one part of the electronic circuit according to (6)
10. The nanosensors according to (1) will be contacted at either end by nanocontacts according to (6)
11. The nanocontacts according to (6) can be in the form of chips (bulk structures), thin films or wires according to (7)
12. The nanocontacts according to (6) must be of sufficient dimension to contact the nanosensors according to (1)
13. The aircraft chassis to be made of a composite that is compatible with the nanosensors according to (1)
14. The entire array to be flexible and replaceable for emergency repairs, ie ease of refit

15. The array can also act as an anti-static coating and thermal conductor according to (1)
16. The array can act to strengthen the structure of the aircraft under differing conditions
17. The database method is carried out for claim (1) by analyzing a electronic data and collected from the nanosensors of (1) and transferred from the nanocontacts of (6) to the database:
    a) Providing data representative of a changes in conductivity (thermal and electronic)
    b) Computing whether the change is due to shifts of the nanosensors or actual fractures by comparing to previously stored data
    c) Incrementing a point in the relevant stress/strain/thermal/DC&AC position as a reference data-point is compared against it
    d) The data to be placed into a grid pattern for mathematical analysis and go/no go options
18. The method of Claim (17) further comprising the step of evaluating the value by a pre conceived rule for determining whether tolerances are acceptable has occurred.
19. The method of Claim (18) further comprising the step of displaying the determination of whether a match has occurred.
20. The method of Claim (17) further comprising of the steps in relative order:
    a) The step of normalizing the collected and stored thermal and conducting data
    b) Comparing the normalized collected and stored thermal and conducting data
    c) Rejecting the thermal and conducting data if the difference in the comparing step exceeds a predetermined amount.
24. A method for analyzing a sample signal with a reference signal for databasing and in-flight recording and safety analysis
25. The invention according to (1) can also be applied to all automotive equipment such as cars, trucks, buses, boats, trains, space vehicles, satellites, rockets and missiles
26. The invention according to (1) can also be applied to buildings for structural information

**Field:**
Method/Device to monitor, inspect and detect flaws in critical to safety/airworthiness aircraft polymer composite structures. It is an aspect of the present invention to provide nanosensors capable of more efficiently obtaining structural information on the aircraft while in flight. While this would permit an aircraft of having a greater working life as well as lowering the downtime for maintenance, more critically it enhances the structural security of the aircraft for safety reasons.

**Background/Object of Invention:**

Polymer Matrix Composites are used in a variety of structural applications in the aerospace industry for numerous reasons including overall weight savings and improved stability and durability. Breakthroughs in Nanotechnology, more specifically, nanocomposites have significantly reduced weight and cost of these materials while enhancing other features beneficial to both military and commercial aircraft. Still, both the FAA and the NTSB require that routine nondestructive inspections take place at periodic intervals to ensure safety of flight. These mandated inspections focus on damage caused by impact, flight induced stress or manufacturing defect. Currently, most of these inspections are time consuming, expensive and result in significant down time of the aircraft. Embedding nanosensors into PMCs for critical structural airframe components can not only enable higher yield manufacturing processes through immediate feedback on process-induced flaws but also enable a realtime in-flight monitoring of critical components. This information can be integrated over time to better predict life expectancy and provide valuable information for improvements to structural component designers and manufacturers.

In order to be effective, the detection and discrimination of potentially dangerous structural information from the chassis of the aircraft must be optimally determinable at the location where such distortions and defects appear, that information being made readily available. For example, being able to identify cracks within the airframe without having to use time consuming and expensive optical acoustic instruments on the ground. Having the necessary information would allow the aircrew to be able to determine the worthiness of the aircraft for flight, take precautionary measures if the damage is serious without endangering life or risking the destruction of the aircraft. To do so effectively, it is necessary to possess the information onboard as the risk or damage occurs. In most instances, catching the first defects will prevent later heavy maintenance, it also allows aircraft maintenance crews the chance of quickly identifying where the damage is done without having to waste time using bulky and expensive equipment.

It is yet another aspect of the present invention to provide the method and system of detection which do not require an overhaul of the entire aircraft. The aircraft can then be allowed to stay in the air for longer periods if there is no structural damage done to the aircraft.

While detection of defects in an aircraft can be done on the micro level using optical acoustic sensors and x-ray equipment, none of this can be done in flight. This equipment may also be used by ground crew for more vigorous testing. However, the onboard computer for data basing can give a history of structural effects for the entire flight of the aircraft. This information will give aircraft manufacturers greater information on the exact stresses and tolerances are required by their aircraft during flight conditions. It would also allow the development of highly specialized aircraft specifically designed for extreme conditions, or for that matter for aircraft in more temperate climates.

It is still another aspect of the present invention to provide software and data handling methods that can be used in the aircraft with convenient expediency.

Currently there is available certain information stored in an onboard computer, but this information does not deal with nanoscale tolerances or such critical information in such detail.

There have been some approaches to providing nanoscale detection using different methods, but none of it addressing in flight methodologies.

The nanosensor array can also be applied to other areas of transportation such as cars, trucks, trains, motorbikes, boats and ships. As the push for greater information and control continues, on board diagnostics becomes even more important in day-to-day life.

The nanosensor arrays can also be applied to rockets and missiles. For missiles it is important to be able to determine stress and failure. In addition it may also be used to receive and send signals from other sources. These can also be the basic architecture for new stealth materials.

The nano-arrays can also be used for space vehicles. The continuous information gathering ability will make space travel safer and more efficient.

As the nano-arrays can be used to receive information, they can also be used to send information. This information could also be used as a replacement of fly by wire systems, reducing the overall weight of the vehicle.

Carbon nanotubes have been discussed before as being potential nanosensors or nanodetectors, without actually producing the device for such an application. We are using the nanotubes as the sensors, but other nanostructures would also be sufficient as long as they could carry current and be affected by changes in thermal environments. It is the link between detection, nano-electronics and software that makes this package unique and critically different than any device before.

## Summary of the Invention

The various aspects and principles are addressed with the present invention which provides a nanosensor array, the information passed onto nanocontacts, those nanocontacts then passing on information to an onboard data base system. The components of the invention are nanosensors, nanocontacts, electronic interconnects between the airframe and the in-flight computer and finally the data base system with the in-flight routine testing algorithms to pass on critical information to the flight crew and maintenance crew. This whole process is expected to be carried on throughout the lifetime of the aircraft, giving a history of the conditions the flight experienced as well as structural information on the composition of the materials used in constructing the aircraft. This data-base routing then allows flight crews to react to inflight potential hazards before conditions in the aircraft become too risky. The benefit of having such information is reducing the risk to life; the aircraft spends less time down for periodic maintenance and could extend the lifespan of an aircraft. Additional benefits are that the nanocomposites can also act as structural enhancers, antistatic coatings and thermal conductors.

Fig1: Schematic of Nano array

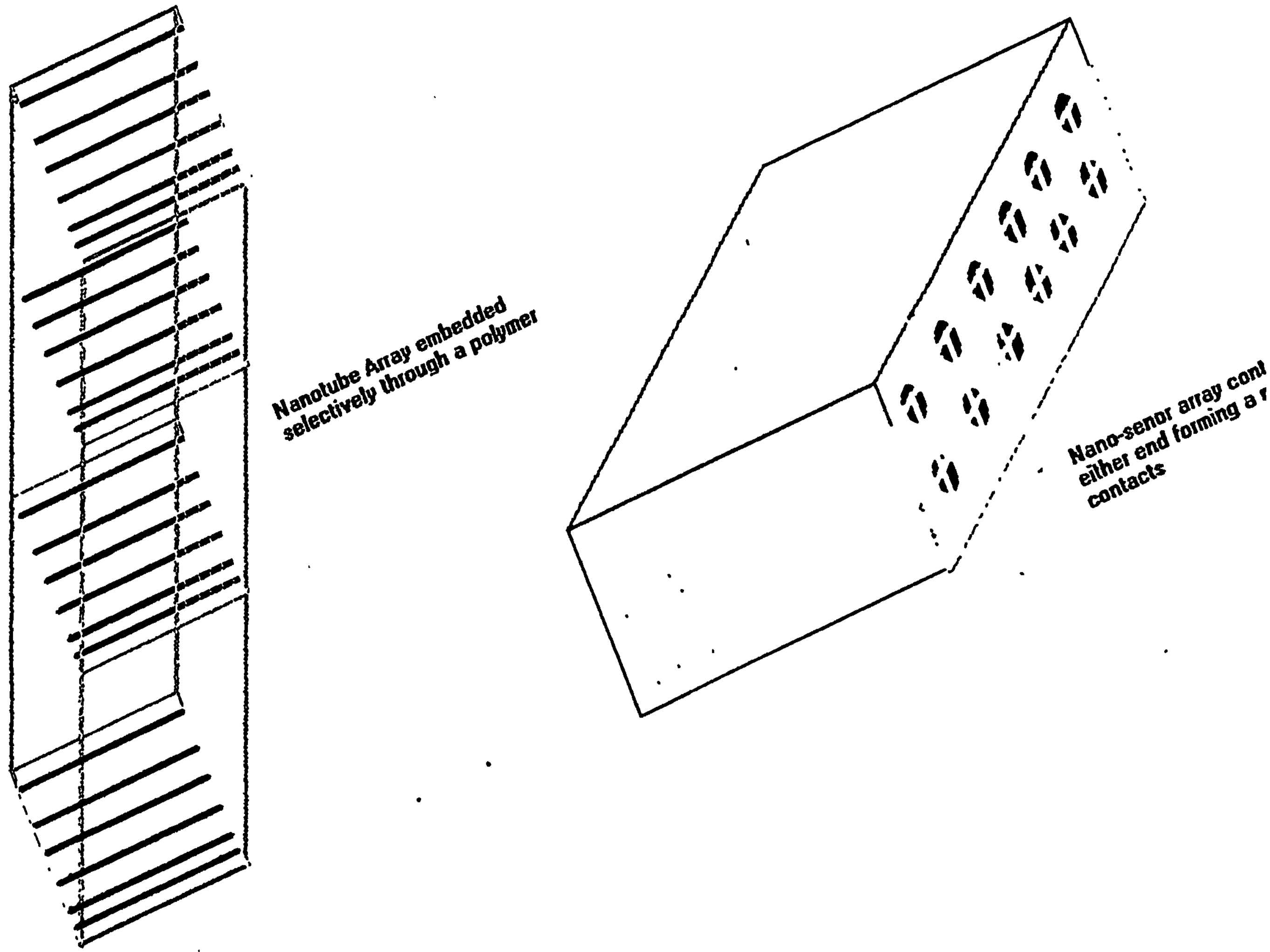
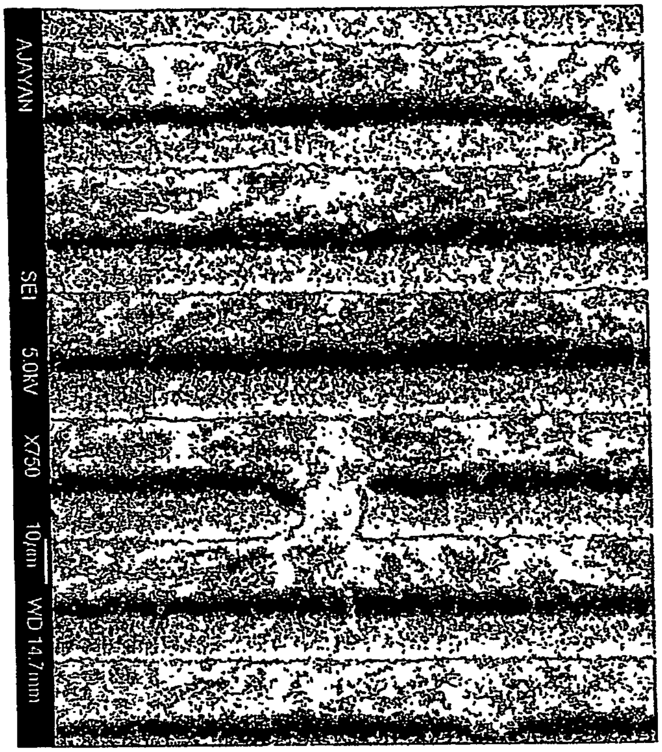


Fig 2: Aligned Nanotubes



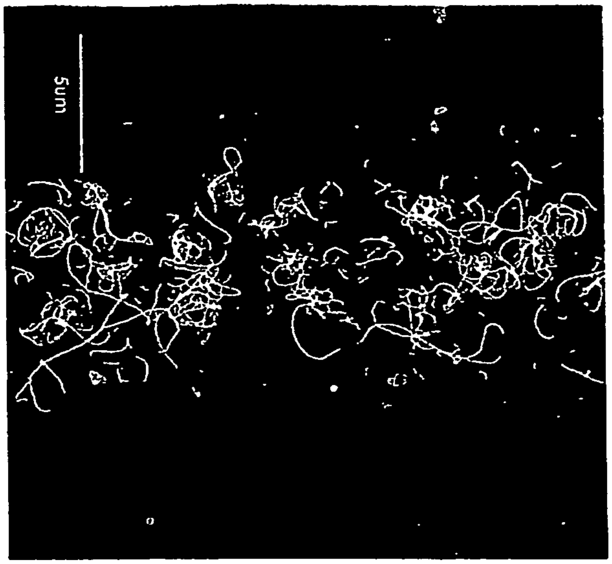



Fig 3: Controlled isolated NT growth

Fig 4 : Composite Formed From aligned tubes in Selected areas

Fig 5 : Aligned Arrays of Composite